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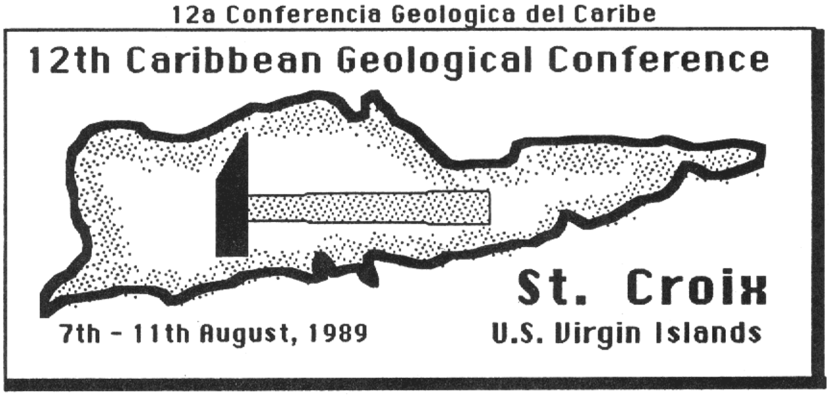

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Extensional Tectonism in the Mona Passage, Puerto Rico and Hispaniola: A Preliminary Study

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ABSTRACT

The Mona Passage, separating the Puerto Rican block from Hispaniola, is dominated by three sets of active normal faults. The northernmost is the 19° lat (latitude) Fault, a south-dipping normal fault separating a metamorphic complex on the north from an arc complex on the south. The second is the Mona Canyon, a relatively straightforward north-south trending graben (Gardner and others, 1980) that cuts the 19° lat Fault, and has a throw of over 2 kms and cumulative heave on the order of 10 kms. South of the Mona Canyon is a complex of normal faults, some with throws up to more than 2 kms. This complex of normal faults reaches from the southern termination of the Mona Canyon south to the uppermost limit of Muertos Trough (trench) accretion, crosses southwest Puerto Rico and heads offshore in the southcentral Puerto Rico region, and has not been traced as of yet to the west. This extension complex, a myriad of normal faults probably connected by transfer zones, is here proposed to represent a large (over 100 km by 100 km) extensional allochthon, sliding into the Muertos Trough. The 19° lat Fault may indicate that a larger extensional allochthon underlies much of the Mona Passage. The relationship between the two extensional allochthons is not known with certainty.

INTRODUCTION

This is a preliminary description of the geology of the Mona Passage, which lies between the islands of Puerto Rico and Hispaniola (Fig. 1). The Mona Passage provides a continuous seaway from the Muertos Trough (Trench) to the south, across the non-volcanic arc massif of the eastern Greater Antilles, to the Puerto Rico Trench on the north. Most previous studies have emphasized the important of convergence in the trenches (Ladd and others, 1977; Ladd and Watkins, 1978; Ladd and others, 1981; McCann and Sykes, 1984) and strike-slip faulting (Mann and Burke, 1984; Mann and others, 1984). Herein, we present evidence for large magnitude normal faults in the Mona Passage. Much of our study is based on analysis of seismic reflection lines collected by Western Geophysical Inc. for the Puerto Rico Electric Power Authority in the 1970's, and two seismic lines presently owned by the Texas Institute for Geophysics.

SEISMIC STRATIGRAPHY OF THE MONA PASSAGE

Based on preliminary study of seismic lines in conjunction with information from dredge hauls, and submersible surveys (Fox and Heezen, 1975; Weaver and others, 1975; Perfit and others, 1980; Heezen and others, 1985), a two-part stratigraphic sequence is recognized in the Mona Passage. The lower part of the seismic stratigraphy is acoustic basement, which can be shown through correlating rock data from dredge hauls and seismic lines, to represent island arc basement, except in the far nothern part of the Mona Passage, where the acoustic basement is a metamorphic complex (Perfit and others, 1980). The acoustic basement is generally structureless, though in a few seismic lines reflectors are observed which may be faults. Lying above acoustic basement is layered, shallow-water-facies, middle Tertiary rocks (Oligocene, Miocene), again correlating dredge haul and seismic information. Because these rocks are found in scarps of normal faults, it is known that at least some of the normal faulting in the Mona Passage is Miocene or younger.

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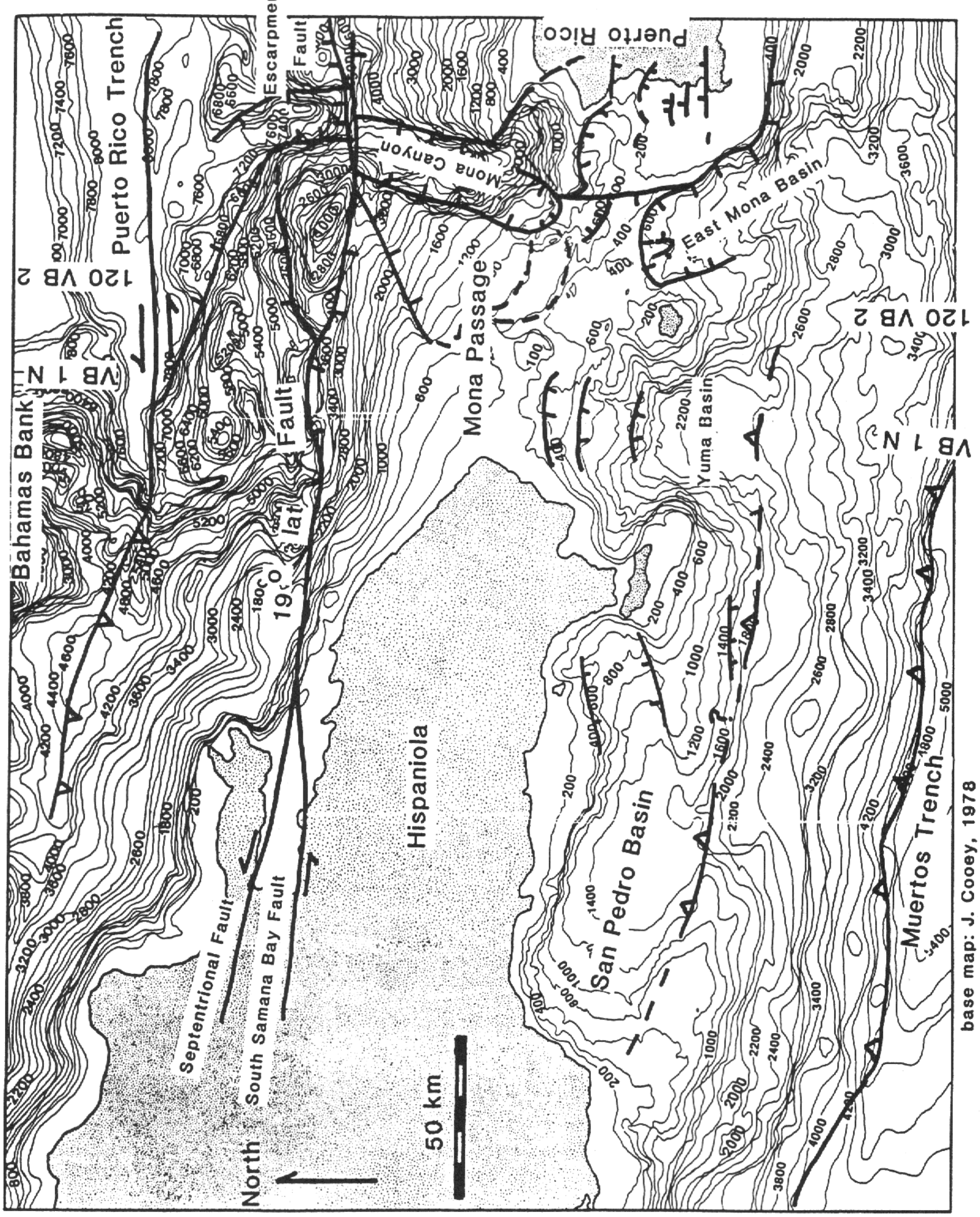
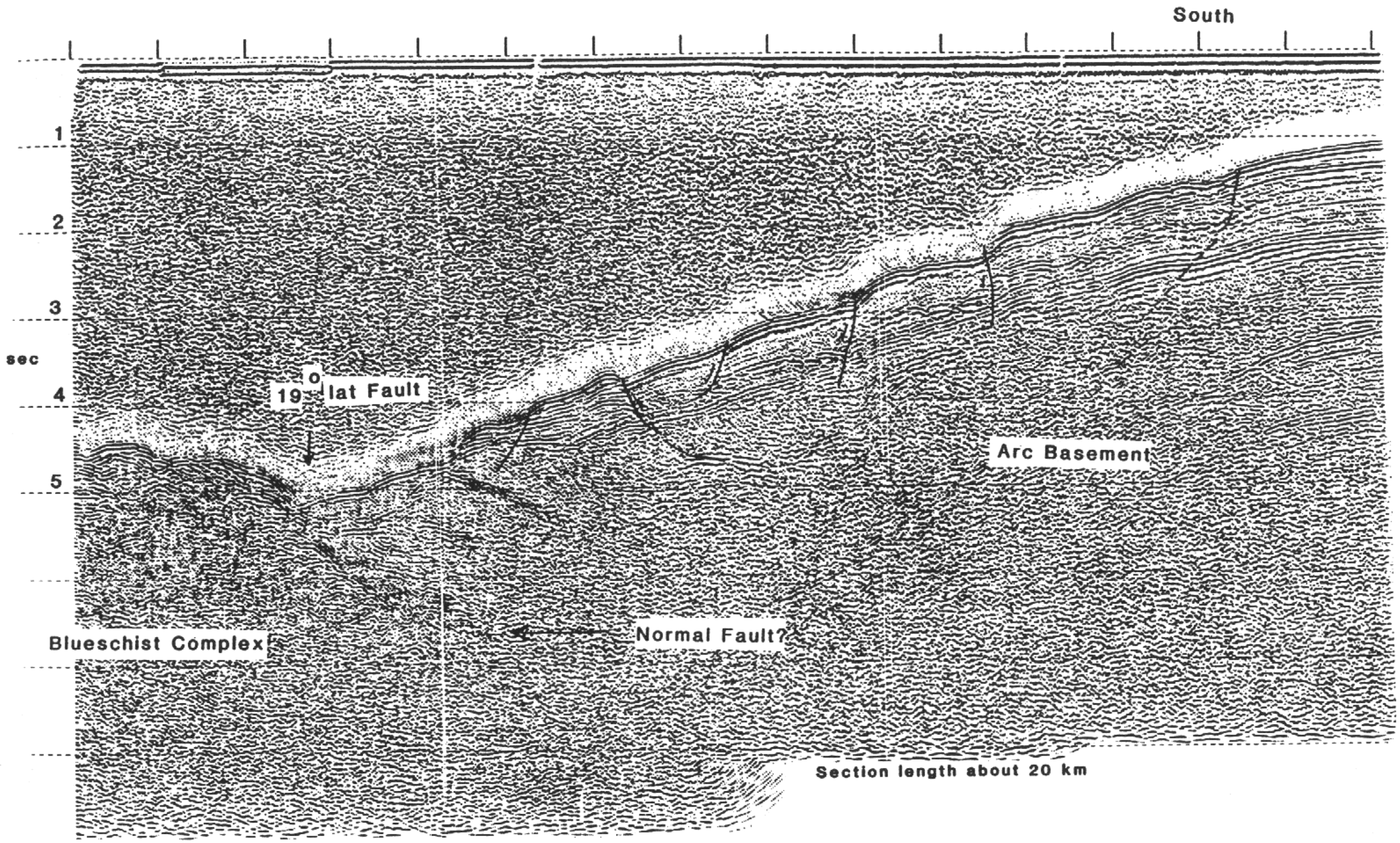


1. Location map of the Mona Passage between Hispaniola and Puerto Rico (bathymetry from Cooey, 1978, unpublished). Tectonics south of eastern Hispaniola are from Ladd and others (1981). VB 1 N and 120 VB 2 are two seismic lines owned by Texas Institute for Geophysics, and studied with their permission here. Positions of Septentrional and South Samana Bay Faults from Mann and others 1984. The Escaprment Fault is a north-dipping normal or oblique normal fault, responsible for the northward downward step in the Mona Canyon across the 19° lat Fault (Larue and others, 1990).



2. Line VB 1 N. Image of the 19° lat Fault, showing southward dip and rollover of Tertiary strata. Evidence for blueschist complex is from Perfit and others (1980) based on dredge hauls.

19^{o} LATITUDE FAULT

The 19^{o} lat (latitude) Fault is the offshore extension of the Septentrional and Samana Faults of Hispaniola (Fig. 1). Based on dredge haul information, the fault separates a metamorphic basement terrane to the north from an arc basement terrane on the south (Perfit and others, 1980). Migration of a seismic line crossing the fault indicates that it is probably a normal fault, dipping south (Fig. 2). Layered Oligo-Miocene strata define a rollover, indicating the 19^{o} lat Fault is probably listric at depth. It is estimated that if the fault is indeed listric, the decollement could be as deep as the base of the arc crust near 30 km. This may indicate that in the Mona Passage, the arc massif is part of an extensional allochthon.

Normal faulting on the 19^{o} lat Fault may be responsible for regional subsidence of Late Miocene age to the south of the 19^{o} lat Fault originally described by Schneiderman and others (1972), Perfit and others (1980), Le Pichon and others (1985), Birch (1986), Moussa and others (1987).

MONA CANYON

The Mona Canyon can be divided into a northern and southern section, separated by the 19^{o} lat Fault. The canyon trends NW, north of the 19^{o} lat Fault, and N, south of the 19^{o} lat Fault. Abundant multichannel seismic data are available for the southern part of the graben, and limited single-channel data are available for the northern part (Fig. 3,4). Wall rocks of the canyon have been dredged and described by Weaver and others (1975), Fox and Heezen (1975) and Perfit and others (1980). In addition, Heezen and others (1985) described observations from a submersible investigation. The structure of the canyon seems to be a simple graben (Figs. 3,4) indicating E-W extension. As indicated by a large earthquake in 1918 (magnitude 7.5; Gardner and others, 1980), and a moderate earthquake in 1987, the graben is seismically active.

The southern termination of the graben is peculiar. The graben faults fan to the east and west, and form a "Y" pattern. The origin of this fanning pattern is uncertain, and has not been addressed in previous work.

NORMAL FAULTS BETWEEN ISLA DESECHEO AND THE MUERTOS TROUGH: THE MONA ALLOCHTHON

South of the "Y" shaped termination of the Mona Canyon, there are an abundance of normal faults with arcuate bathymetric traces. These faults have maximum throws of greater than 2 kms, and clearly cut deeply into basement. These have been mapped by Western Geophysical Company and Fugro (1974), but not interpreted. Their work relied only on the seismic reflection data, and did not stress the correlation between bathymetry and active faulting. In a preliminary map, we restudied all the seismic lines, and have reinterpreted the map traces of the faults (Fig. 3). All seem to have normal displacements, and if the arcuate patterns are indeed correct, little strike-slip displacement is indicated.

Normal faults occur in southwest Puerto Rico, cut rocks as young as Miocene, and some are seismically active. Several onland lineaments can be traced offshore, and linked to faults seen in seismic records.

The depth to the base of the Mona allochthon decollement can be approximated by using balanced cross-sections (Fig. 4). Preliminary calculations indicates a decollement depth around 6 kms, which correpsonds to the depths of the Muertos Trough. It is thus possible that this purported large slide block is contributing to the deformation in the Muertos Trough (Fig. 5).

TENTATIVE EXPLANATIONS FOR NORMAL FAULTING IN THE STUDY AREA

We tentatively conclude that two directions of extension are indicated: E-W for the Mona Graben, and N-S for the region south of the Mona Canyon and the 19^{o}lat Fault. A number of explanations can be proposed for these two extension directions. Faults south of the Mona Canyon may have formed by slope failure (mentioned briefly for smaller normal faults southeast of Hispaniola by Ladd and others, 1977). However, simple slope failure cannot explain the vertical throws of 2 kms on the Desecheo Ridge fault, and the southern "Y" part of the Mona Canyon fault, where it opens into an east-west orientation. Furthermore, simple slope failure does not explain why most of the normal faults cut arc basement rocks. Thus, we tentatively conclude that simple slope failure cannot explain the province of normal faults south of the Mona Canyon graben.

The two directions of extension may be related to a single NW-SE extension, where the sums of their extensions are additive. Rotation of the Puerto Rico block could also conceivably explain some of the normal faults. The solution we

3. Interpretation of normal fault patterns in the Puerto Rican territorial waters of the Mona Passage. Note grid coverage. Data collected by Western Geophysical Inc., and owned by the Puerto Rico Electric Power Authority.

tentatively propose is that the faults south of the Mona Canyon represent an extensional allocthon (Fig. 5), slipping toward the Muertos Trough. This allochthon is structurally on top of an extensional boundary, represented by the Mona Canyon north of the allochthon, between Hispaniola and the Puerto Rican block.

The 19^{o} lat Fault, which has an apparent extension direction parallel to that of the Mona allochthon (although motion probably is oblique left-lateral, based on plate motion studies), is thought to represent extensional tectonism in the Puerto Rico Trench, either associated with Caribbean plate motion or related to rotation of the Puerto Rico block (Larue and others, 1990).

SIMILAR STRUCTURES FOUND ELSEWHERE

Large extensional allochthons similar to the Mona allochthon have been observed in several other places in the world. First, and most obviously, there is soft-sediment deformation of significant scale associated with delta fronts such as the Gulf Coast and the Niger Delta. Deformation in these delta fronts is probably as deep as several kilometers, and thus similar to what is described herein. The Mexican Ridges (Buffler, 1979; Buffler, 1983) are especially interesting, because at the base of a large gravity slide, a thrust belt is developed. Also off southwest Africa, a large extensional allochthon with a fold and thrust belt at the toe is developed (Coffin and Rabinowitz, 1983), probably the largest submarine extensional allochthon recognized, according to the authors. However, these examples involve weakly lithified materials, in contract to the arc basement lithologies involved in the Mona allochthon.

Normal faults with large offset are found in arc platform settings. For example, the summit basins of the Aleutian arc, described by Geist and others (1988), are bound by oblique normal faults with large displacements.

We must also consider the possibility that the accretionary complex of the Muertos Trough is not a typical one formed by plate convergence, but instead, simply the toe of the extensional allochthon (the continuation of the accretionary complex to the east would be due to the coalition of various extensional allochthons). No Benioff zone has been recognized beneath the Muertos Trough, and few earthquakes have been associated with the subduction (Ascencio, 1980; Byrne and others, 1984). This interpretation is not favored at present, because the accretionary complex seems to be too large to be associated with the extension observed in the Mona Passage, even if extension from the 19^{o}lat Fault is included. The upper limits of accretion extend some 40 kms inboard from the base of the accretionary complex, and it is unlikely that all accretion is related to the proposed extensional allochthon. Rather, we think it likely that the Muertos trough accretionary complex is accentuated by deformation at the toe of the proposed Mona allochthon.

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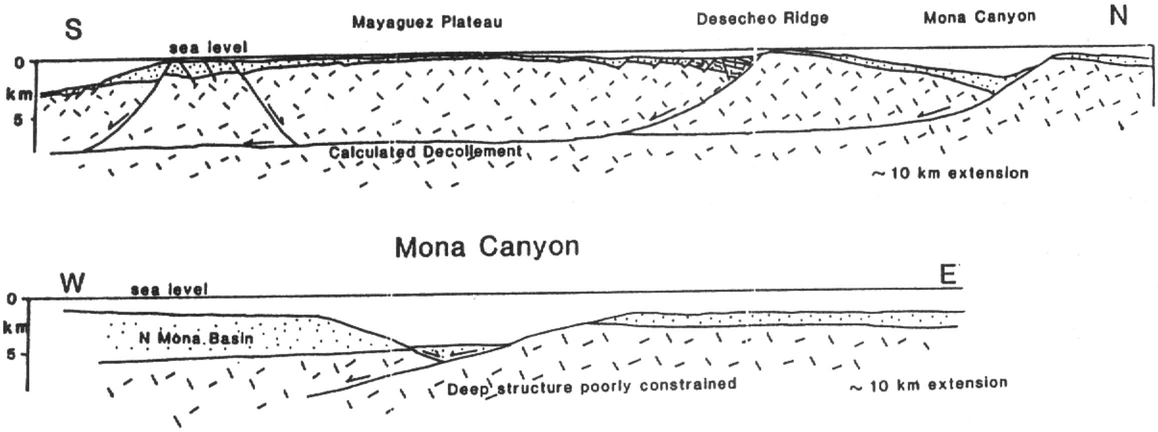
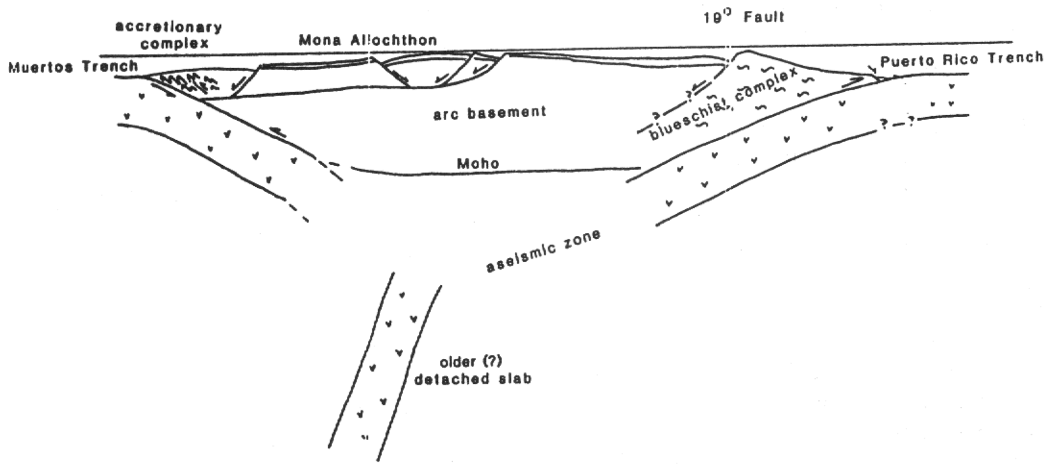


4A,B Interpreted line drawings for Line 406D and 103D of Figure 3.



5. Cross-section through the Mona Passage. Positions of down-going slabs from seismic data (McCann and Sykes, 1984; Byrne and others, 1985). Base of Moho from gravity and refraction data (Talwani and others, 1959). Line of section is generalized to include several features.

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